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SPACE ECOLOGY (BASED ON MATERIALS OF 22nd INTERNATIONAL CONGRESS ON ASTRONAUTICS)

K. Ya. Kondrat'yev

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16. Abstract

Reports on the problem of utilization of satellites for studying natural resources of the earth, presented at the 22nd International Congress on Astronautics, are reviewed in this article.

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SPACE ECOLOGY (BASED ON MATERIALS OF 22nd INTERNATIONAL CONGRESS ON ASTRONAUTICS)

K. Ya. Kondrat'yev[1]

The main theme of the 22nd International Congress on Astronautics, held in Brussels from 20-25 September 1971, was: "Application of Space Technology for Satisfying the Basic Needs of Mankind." The scientific meetings on meteorology, natural resources analysis and the problem of atmospheric and oceanic pollution (the cochairmen of the committee and sessions were Doctor L. Jaffe, Director of the Applied Satellite Program of NASA, and Member--Correspondent Academy of Sciences USSR K. Ya. Kondrat'yev), organized by the Committee on Applied Satellites of the International Astronautics Federation (IAF), contributed significantly to the proceedings of the congress. The purpose of this review is to discuss some recent results in reference to the field of space ecology and the application of artificial earth satellites for studying the environment and natural resources. /108*

Experiments conducted aboard the "Soyuz" Soviet manned spaceships [2, 4, 5, 7, 8], U.S. experience in space photography of the earth [6, 20], numerous theoretical developments and airborne measurements have proved the feasibility of using artificial earth satellites for studying the environment and natural resources [3]. This is why the United Nations Committee on the Peaceful Use of Space is expressing so much interest in the above-mentioned topic [15, 17].

The group of reports presented at the congress by Soviet specialists on the problem of the application of artificial earth satellites for investigation of the environment essentially reflected the findings presented in [2, 4, 5, 7, 8].

B. Lundholm's report [18] presents a detailed discussion of the capabilities of artificial earth satellites (AES) in application to natural resources studies. He emphasizes the need for investigating the global pattern of ocean and air pollution and the biological productivity of the

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*Numbers in the margin indicate pagination in the foreign text.

ocean. W. Fischer [14] presents examples of using space photographs for making maps on the scale of 1:500,000 for the Phoenix area in the United States.

The problem of the economic effectiveness of such methods becomes very important in connection with the problem of the application of space methods for natural resources studies. This aspect of the problem was discussed in a report by R. A. Casruccio [11], in which was stressed the need for developing ecological models that determine both economic advisability and the information content by way of example of problems on oceanology and hydrology.

One of the most important problems involved in increasing the productivity of agriculture consists in doubling (and perhaps quadrupling) the fish harvest by the year 2000. In view of the difficulty involved in evaluating the economic effectiveness of the solution of such a problem it may be assumed that the economic result will amount to an annual saving of at least 10-20 billion dollars. Naturally, the solution of the examined problem will require, on the one hand, greater yield efficiency and, on the other hand, the need for exercising the corresponding concern about reproduction of fish reserves. Forecasting the migration characteristics of fish schools and the environmental conditions that influence fishing operations is extremely important in this connection. Included among such characteristics are the following:

1) the location, size and average movement of fishing regions; /109
2) fish population density in the fishing regions;
3) the depth at which fish schools live;
4) the "mean free path" between schools;
5) makeup of schools (by species);
6) sizes of the species and their living habits;
7) ocean surface state;
8) weather conditions (wind, cloud cover, ice, etc.);
9) factors that are possibly injurious to fish or detract from their living conditions (ocean pollution, etc.).

In the absence of forecasts of the above-mentioned characteristics the ratio of the time spent on the search for and catching of fish is about 10:1. The construction of fish catch models makes it possible to determine the most important parameters.

For example, according to one model the most important information concerns the surface temperature of the sea, vertical temperature profile and salinity. Comparison of various models suggests that the most important parameters are the following: a) vertical profile and change of temperature beneath the surface; b) salinity; c) chlorophyll content; d) evolution of cloud cover conditions; e) chemical composition of sea water; f) surface wind conditions. Many of the above-mentioned parameters can be determined through remote methods. Some, however (for example chemical composition), require direct measurements. This means that the optimum way of solving the problem involves the combined utilization of satellite (indirect) and direct (sea buoys) measurement methods, using satellites for collecting and transmitting information from automatic sea buoys.

Fresh water resources is another big problem. This problem, as we know, is becoming increasingly acute, since 97% of the world's water supply is made up of the salt water of the oceans, and 95% of the remaining 3% is fresh water, "locked in cold storage" in polar glaciers. The explosive increase in the demand for, and the limited reserves of fresh water pose the problem of detailed analyses in the field of continental hydrology (precipitation on land in the final analysis represents the main source of fresh water at the present time). One of the specific problems is detailed analysis of water shed areas, which requires first of all determination of the total precipitation, fallout time, soil humidity, fluctuations of the water table and river flow rates. From the standpoint of determination of all these characteristics the situation is similar to the problem of the fishing industry: only a combination of satellite and direct measuring methods will provide a sufficiently effective solution.

F. Shahrokhi and J. P. Rudy [22] discussed the practical capabilities of such a combined approach by way of example of the solution of various problems of natural resources analysis in the Southeastern United States and estimated the resulting economic savings. A general description of the economic effectiveness of investigations in various areas is presented in Table 1. These estimates, of course, are rough and tentative, but they nevertheless offer an idea of the economic effectiveness. As regards problems that are peculiar to the Southeastern United States, they include primarily studies in forestry and agriculture, water resources, water and air pollution.

TABLE 1. ECONOMY OF SPACE METHODS OF NATURAL RESOURCES STUDY

Field of study	Estimated annual saving (in dollars)
Hydrology, geology, physico-geographical mapping, resource management	70-80 million
Fishing industry, ocean resources utilization	10-200 million (U.S.); 0.9-2.0 billion (world)
Agriculture and forestry	20-100 billion
Hydroelectric power utilization, rice and wheat productivity, combatting malaria	12 billion over 20 years
Irrigation in California	50 million

The data that are necessary for the solution of the respective problems /110 can be obtained through photography in various bands of the spectrum and by using multichannel scanning radiometers for reproducing the pictures. By using this type of automatic (computer) data processing it is possible to make maps that characterize the distribution of various types of vegetation and its state, soil varieties, etc. Interpretation of the pictures in this case involves both analysis of each individual picture and correlation analysis of pictures in the various bands of the spectrum (from the Apollo manned spaceship). Table 2 characterizes the specific capabilities of interpretation of space photographs, taken in various bands of the spectrum. The conventional symbols used in Table 2 are defined as follows: 1 -- interpretation always possible; 2 -- interpretation usually possible; 3 -- interpretation sometimes possible; 4 -- interpretation impossible.

Quantitative economic analyses with the aid of space vehicles require the development of the indices that characterize various phenomena. A preliminary discussion of such indices was presented in a report by W. O. Davis [12]. An example of a system of indices that can be determined on the basis of space observations (in reference to conditions in the United States) is presented in Table 3. This example, of course, should be viewed simply as an illustration of a possible approach to the indexing of natural phenomena.

TABLE 2. CAPABILITIES OF INTERPRETATION OF MULTISPECTRAL PHOTOGRAPHS

Characteristic	Band of spectrum, μ			
	Color IR 0.51-0.89	Blue-green 0.47-0.61	Red IR 0.68-0.89	Yellow-green 0.59-0.715
Type of vegetation	3	4	4	3
Phase of vegetation	1	4	2	4
Pastures	2	2	3	2
Sand	1	1	2	1
Rock outcroppings	1	1	2	1
Rivers and reservoirs	1	2	2	3
Dry bed	1	3	2	3
Lake	1	2	2	2
City	3	3	4	3
Buildings	4	4	4	4
Shafts	4	4	4	4
Highways and railroads	1	2	2	1
Airfields	1	3	3	1
Pavement composition	4	4	4	4

The capabilities of interpretation of space photographs for geological purposes are reviewed in a report by P. D. Lowman [16], presented by L. Jaffe. In this work, which was prefaced by a brief review of the history of space aerial photography, are discussed in detail four examples of analysis that illustrate the advantages of space photography (photographs from the manned spaceships Gemini and Apollo): 1) discovery of previously unknown faults in Southern California; 2) discovery of a new region of volcanic activity in Northern Mexico; 3) reliable interpretation of the so-called Texas lineament as an extensive fold and fault zone; 4) proof of the importance of wind erosion as a factor in the formation of the relief in North Africa.

As regards the importance of space photographs in general, they may be /111
used in place of aerial photographs. But apart from this there are three other very important applications: 1) comparison of photographs with existing geological or topographic maps, which often makes it possible to greatly refine these maps; 2) comparison of photographs of remote, but similar regions (for example the deserts of North America and North Africa), which promotes more complete interpretation of data on these regions; 3) utilization of space photographs for the solution of geological problems for a given region (the Texas lineament, for example). It must be emphasized, therefore, that space

TABLE 3. ECOLOGICAL INDICES

Investigated phenomenon	Vegetation cover	Phenology	Urban green-belts	Land utilization	Harvest	Biocomplexes	Marine chlorophyll	Oil films	Population	Forests and forest fires
Index	% of territory	% of green in zone between 30 and 40° N. lat. on 15 April	% green on 1 July	Ratio to optimum	Ratio to optimum by type	Ratio of types by area	Number of phytoplankton per m^3	km^2/km of coastline	Ratio	Phenomenon-area

photographs are not simply pictures of the earth, taken from great altitudes, but are a qualitatively new source of information [3].

Great significance is now attached to the development of methods of remote determination of soil characteristics (especially humidity and temperature). Microwave radiation measurement data have been used successfully for this purpose [1, 9, 16]. Interpretation of the results of measurements of the polarization of ground--reflected short-wave radiation on about 0.5 μ wavelengths should also be considered promising [23, 24]. This capability is determined by the strong increase of polarization of backscattered sunlight as soil humidity increases (in the presence of saturating moisture the light reflected at the Brewster angle is completely polarized), especially for large angles of reflection. Important in this regard is the fact that the change of polarization depends little on the angle of incidence of solar radiation. A sufficiently reliable solution for this problem is possible, however, only after preliminary identification of the type of soil, since polarization conditions during the reflection of light by different soils are specific.

The increasing demand for food products is focusing more and more attention on the biological resources of the oceans of the world. Since the biological production of the oceans is determined by the process of photosynthesis, the need arises for the development of methods of monitoring the spatial distribution and dynamics of photosynthetic activity, which, of course, must be remote methods, since the use of direct measurements is greatly limited.

The key indicator of the biological productivity of the oceans is chlorophyll. Therefore measurements of the concentration of chlorophyll and its variations will characterize the rate of photosynthesis processes and biomass production conditions. On the other hand, the rate of photosynthesis (and, consequently, the rate of production of the biomass) depends on the availability of such nutrient components as nitrogen and phosphorus.

Pollutants have an important influence on photosynthesis activity. Thus, for example, the presence of mercury in the concentration of 10^{-9} inhibits photosynthetic activity by 50%. A DDT concentration of 10^{-8} also significantly suppresses photosynthesis processes. Thus, chlorophyll measurement data give an idea both of the concentration of biomass (photoplankton) and of associated factors (nutrient and pollutant concentrations).

Since data are available that show that the chlorophyll concentration correlates with the ocean surface temperature, it is important to conduct simultaneous remote measurements of both these parameters. The combined measurement data on chlorophyll and surface temperature are important also from the standpoint that they can be used for characterizing regions of upwelling of deep cold waters to the surface, for defining zones of ocean currents and of waters of different origin.

Only the window of transparency of the atmosphere in the visible band of the spectrum can be used for development of the remote chlorophyll measuring method, since radiation penetrates deeply enough into water (up to 150 m) only in this range of wavelengths. Proceeding from such considerations J. C. Arvesen et al. [10] conducted airborne spectral measurements of the radiation reflected by the ocean surface in the 380-1,100 nm band. The double monochromator (with a ground and diffraction grid) which they used had a spectral resolution of the order of 1 nm (the backscattered radiation was aimed into the instrument, installed aboard a Cessna-401 airplane, by means of fiber optics). Analysis of the backscatter spectra obtained showed that chlorophyll absorption bands are distinctly identifiable on them.

However quantitative interpretation of the backscatter spectra is difficult in connection with the fact that the reflected radiation depends on many factors (in addition to the chlorophyll concentration in sea water). Therefore it turned out to be much more effective to use a differential radiometer [10], which simultaneously measures the intensity of backscattered radiation in the chlorophyll absorption band and outside this band. By measuring the difference (or ratio) of the intensities of the backscattered radiation on a wavelength of 443 nm (maximum absorption) and 525 nm (comparison band) it is possible to determine a characteristic that is extremely sensitive to the chlorophyll concentration. For this purpose the radiometer is calibrated on sunlight, scattered by a Teflon screen. Surface temperature was measured with an infrared radiometer, operating in the 10.5-12.5 μ band with a measuring accuracy of 0.5°C. /112

Comparison of the measurement data with the aid of the differential radiometer at an altitude of 150 m and of the results of direct measurements of chlorophyll concentration by the fluorometric method at depths of from 1 to 10 m (depending on the transparency of the water) revealed that the readings of the radiometer are a linear function of the logarithm of the chlorophyll concentration. The existence of such a sensitive correlation made it possible to conduct continuous monitoring of the chlorophyll concentration (along the flight route) in the range of concentrations from 0.03 to more than 10 mg/m^3.

The application of such data also made it possible to construct a three--dimensional picture of the level of eutrofication of lakes and the distribution of the fresh water zone (plume) in river estuaries. Simultaneous measurements of chlorophyll and surface temperature revealed a distinct negative correlation between these parameters. Naturally the use of the satellite version of the above-described differential technique makes it necessary to solve the problem of the transfer function of the atmosphere, since the influence of the atmosphere cannot be considered completely excluded even in the case of the above-examined differential method.

It is noteworthy that J. P. Millard and J. C. Arvesen [19] used the above-mentioned method for detecting oil films (about 20 μ thick) on the ocean surface, created artificially by dumping different oils from an airplane. Also for this purpose they measured the polarization components of the reflected radiation on the wavelength of 380 nm. They measured the difference of intensities of the polarization components in the plane of flight (in the same plane as the sun) and in the perpendicular plane for the polluted surface in relation to the corresponding value above the clean surface.

The experiments revealed the following: 1) the maximum brightness contrast between the polluted (film covered) and clean water occurs in the ultraviolet (wavelengths less than 400 nm) and red (above 600 nm) bands of the spectrum; 2) the minimum contrasts occur in the range of wavelengths of 450-500 nm; 3) the contrast depends to a great extent on illumination conditions (cloud cover): the greatest contrasts occur in the case of a continuous cloud cover; 4) the ocean surface is always brighter in the presence of an oil film (the radiation is reflected in this case at the level of the upper boundary of the film); 5) no characteristic absorption bands were observed that would permit the distinction of various types of film (oils); 6) the use of polarization measurements is most promising for the detection of oil films.

Of course, one of the most difficult problems involved in the utilization of artificial earth satellites for environmental and resource studies is the development of effective ways and means of processing enormous volumes of data. This theme was the subject of reports by W. E. Scull [21] and J. H. Disher [13], presented on the section "Telemetry and Data Processing." The first of these reports examines the functions of the basic components of the ground-base natural resources satellite (ERTS) data, located at the Goddard Spaceflight Center: 1) the operations control center (which controls the functioning of the satellite and its equipment); 2) the data processing center (responsible for the processing, storage and dissemination of data).

J. H. Disher described the basic objectives of the scientific program of the long-range orbital laboratory "Skylab" (to be launched in the spring of 1973), the main onboard scientific equipment and ground facilities for receiving and processing data (information from the orbital laboratory will be received at 13 ground stations, located at different points around the world). The report describes, in particular, the complement of scientific equipment designed for solving problems related to natural resources studies.

REFERENCES

1. Basharinov, A. Ye. and A. M. Shutko, "Soil Humidity Measurement by High--Frequency Radiometry," *Meteorologiya i Gidrologiya*, No. 9, 1971.
2. Buznikov, A. A., K. Ya. Kondrat'yev, A. I. Lazarev, M. M. Miroshnikov, A. G. Nikolayev, V. I. Sevast'yanov, O. I. Smoktiy and Ye. V. Khrunov, "Visual Observations of Nighttime, Twilight and Daytime Horizons of the Earth from Manned Spaceships," *Kosmicheskiye Issledovaniya*, Vol. X, No. 1, 1972.
3. Vinogradov, B. V. and K. Ya. Kondrat'yev, *Kosmicheskiye Metody Zemlevedeniya* [Space Methods of Earth Studies], Gidrometeoizdat Press, Leningrad, 1971. /113
4. Kondrat'yev, K. Ya., A. A. Buznikov, A. G. Nikolayev, V. I. Sevast'yanov and O. I. Smoktiy, "Results of Visual Observations of Nighttime, Twilight and Daytime Horizons of the Earth from Soyuz-9 Spaceship," *Doklady AN SSSR*, Vol. 197, No. 3, 1971.
5. Kondrat'yev, K. Ya., A. A. Buznikov, O. B. Vasil'yev, B. V. Vinogradov, A. A. Grigor'yev, Yu. I. Rabinovich and L. I. Chapurskiy, "Some Results of Combined Satellite Geophysics Experiment," *Doklady AN SSSR*, Vol. 196, No. 6, 1971.
6. Kondrat'yev, K. Ya., "Studies of the Environment from Space," *Meteorologiya i Gidrologiya*, No. 7, 1971.
7. Kondrat'yev, K. Ya., A. P. Gal'tsev, O. I. Smoktiy and Ye. V. Khrunov, "Colorimetry of the Twilight Sky on the Basis of Spectra Recorded from Soyuz-5 Spaceship," *Doklady AN SSSR*, Vol. 191, No. 5, 1970.
8. Kondrat'yev, K. Ya., A. A. Buznikov, B. V. Vinogradov, V. N. Volkov, V. V. Gorbatko, O. I. Smoktiy and V. M. Orlov, "Some Results of Spectrophotometry of the Earth from Soyuz-7 Manned Spaceship," *Doklady AN SSSR*, Vol. 195, No. 5, 1970.
9. Kondrat'yev, K. Ya. and Ye. M. Shul'gina, "Determination of Certain Soil Characteristics on Basis of Microwave Radiation Data," *Doklady AN SSSR*, Vol. 200, No. 1, 1971.
10. Arvesen, J. C., J. P. Millard and E. C. Meaver, "Remote Sensing of Chlorophyll and Temperature in Marine and Fresh Waters," *Paper Presented for the XXIInd IAF Congress*, Brussels, September 1971.
11. Casruccio, R. A., "The Role of Application Satellites in the Management of the Human Environment," *Technical Report FSC 71-6011*, IBM Corporation, Gaithersberg, Maryland, June 1971.
12. Davis, W. O., "Environmental Quality Indices from Remote Sensing Data," *Paper Presented for the XXIInd IAF Congress*, Brussels, September 1971.
13. Disher, J. H., "Data Management for the Skylab Program," *Ibid.*
14. Fischer, W. A., "Uses of Application Satellites for Inventoring and Monitoring the Earth's Resources," *Paper Presented for the XXIInd IAF Congress*, Brussels, September 1971.
15. "Global Environment Monitoring," *A Report Submitted to the UN Conference of the Human Environment*, Stockholm, 1972, Scientific Committee on Problems of the Environment (SCOPE), Stockholm, 1971.
16. Lowman, P. D., Jr., *Geologic Uses of Earth-Orbital Photography*, Goddard Spaceflight Center, X-644-71-759 (Preprint), Greenbelt, Maryland, August 1971.

17. Lundholm, B., "The Use of Earth Survey Satellites in Monitoring the Changes in the Global Environment," *Committee on the Peaceful Uses of Outer Space, UN General Assembly*, A/AC. 105/C. 1/VIII/CRP, 18 March 1971.
18. Lundholm, B., "Global Monitoring and Remote Sensing from Satellites," *Paper Presented for the XXIInd IAF Congress*, Brussels, September 1971.
19. Millard, J. P. and J. C. Arveson, *Airborne Optical Detection of Oil on Water*, Ames Research Center, NASA, Moffet Field, California, 1971.
20. *Remote Sensing with Special Reference to Agriculture and Forestry*, National Academy of Science, Washington, D.C., 1970.
21. Scull, W. E., "Ground Data Handling for the Earth Resources Technology Satellites ERTS-A and B," *Paper Presented for the XXIInd IAF Congress*, Brussels, September 1971.
22. Shahrokhi, F. and J. P. Rudy, "Remote Sensing Techniques in Evaluating Earth Resources--Study of Potential Uses of ERTS for Southeastern U.S.," *Paper Presented for the XXIInd IAF Congress*, Brussels, September 1971.
23. Steg, L., *Some New Satellite Sensors and Applications*, General Electric Company, Philadelphia, 1971.
24. Stockhoff, E. H. and R. T. Frost, "Polarization of Light Reflected by Moist Soils," *Seventh International Symposium on Remote Sensing of Environment*, University of Michigan, May 1971.

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